727

VOLUME 81 SEPARATE No. 727

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

JUNE, 1955

# THE DESIGN OF PIERS, JETTIES, AND DOLPHINS

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WATERWAYS DIVISION

*{Discussion open until October 1, 1955}*

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**Headquarters of the Society**
**33 W. 39th St.**
**New York 18, N. Y.**

PRICE $0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

# THE DESIGN OF PIERS, JETTIES, AND DOLPHINS

David A. Hopkins,* A.M. ASCE

## CONTENTS

This paper deals with the design of piers, jetties, and dolphins with particular reference to the lateral loads from berthing ships which these structures must withstand.

Design principles are discussed, and two examples of pier design are reviewed:-

a) Guayacan Bay Pier (for Bethlehem Chile Iron Mines) and

b) Hoboken Pier (for the Port of New York Authority).

The paper shows how the impact energy of a berthing ship may be absorbed by the elastic deformation of the structure, without the need for any special system for spring fendering.

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The design of piers and other maritime structures for lateral loads is a subject which is dealt with in many text books. Port and harbor engineers, however, continue to hold widely divergent opinions on the provisions that should be made for lateral loading, and this paper is presented with the object of examining some of the basic assumptions which are made in the practical design of port structures.

Lateral loads due to sea action, wind, or impacts from ships must all be considered, but the heaviest load is usually the last of these three,—the impact of ships when berthing.

To illustrate contrasting types of marine structures, and the trend of modern pier construction, figures no. 1 and 2 show sections of an old fashioned concrete jetty and a representative New York timber pier,—designs that are typical of fifty years ago. These examples represent the two extremes,—the rigid mass concrete jetty, which is not susceptible to damage but may cause damage to ships, and the flexible timber pier which minimizes impact forces by its deflection under load.

Figures no. 3 and 4 are sections of H-piled piers that are described in this paper. It is found that these structures possess some of the flexibility and resilience that gives timber piers their well known resistance to repeated berthing impacts.

### The estimation of lateral impact loads

The critical factor in estimating berthing impact loads is the assumed speed of approach of the ships. The question "What speed of approach should a designer assume as a worst case in order to compute the lateral force on the pier?" is inherently unanswerable by reference to statistical evidence or

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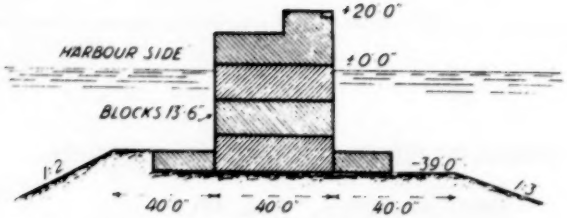



**Figure 1. A mass-concrete pier and break-water at Valencia, Spain.**

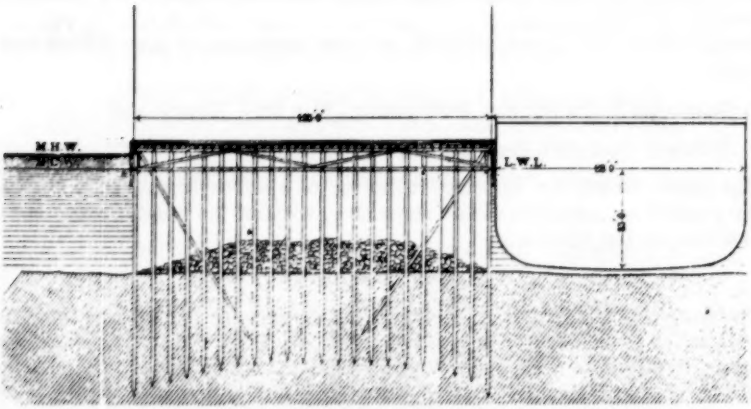



**Figure 2. A typical timber pier built in the North River in 1905.**

experimental data. Damage to piers and fenders is not the kind of subject on which reliable statistics can be easily accumulated. It is unfortunate that, on the rare occasions when a ship's master or pilot makes an error of judgment resulting in damage to the pier or fenders, it is an even rarer occurrence for a competent and impartial observer to be present on the pier at the time.

Some of the factors which will influence the probable berthing speeds are:-

1) The location of the pier or dolphin. A ship in a confined waterway, enclosed harbor or dock is less likely to be moving fast than when it is in an open channel. Enclosed harbors also minimize the risk of high winds blowing a vessel against a pier. Conversely, piers or dolphins in open channels or exposed situations are more liable to impacts at higher speeds of approach.

2) Currents. The presence of river or tidal currents will obviously increase the risk of serious impact due to an error of judgment on the part of the pilot, whereas a ship coming alongside in still water has a better chance of making a smooth approach.

3) Size and type of vessel. As a general rule, the larger the ship, the greater the care with which it is handled and warped alongside. The large passenger lines, for example, are handled with extreme caution when in port,

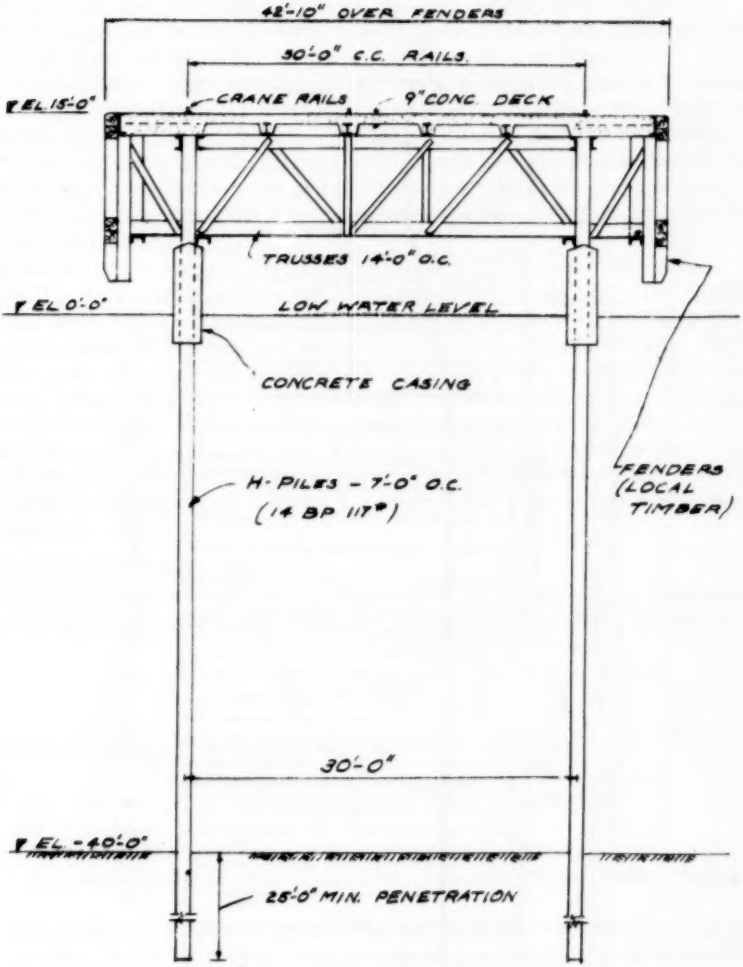



**Figure 3**

**The new Ore-loading Pier at Guayacan Bay, Chile**

while, at the other end of the scale, ferries, tugs and harbor craft are apt to berth with much less respect for the structure which they are coming alongside. These smaller harbor craft are often built with heavy rubbing strakes and thicker plating, and as the ship itself is less liable to sustain damage, even when handled carelessly, it is understandable that the master or pilot will not exercise the same degree of caution when berthing.

4) The type of traffic. Regular dockings by pilots who are familiar with local conditions are likely to be smoother than in the case of ships handled

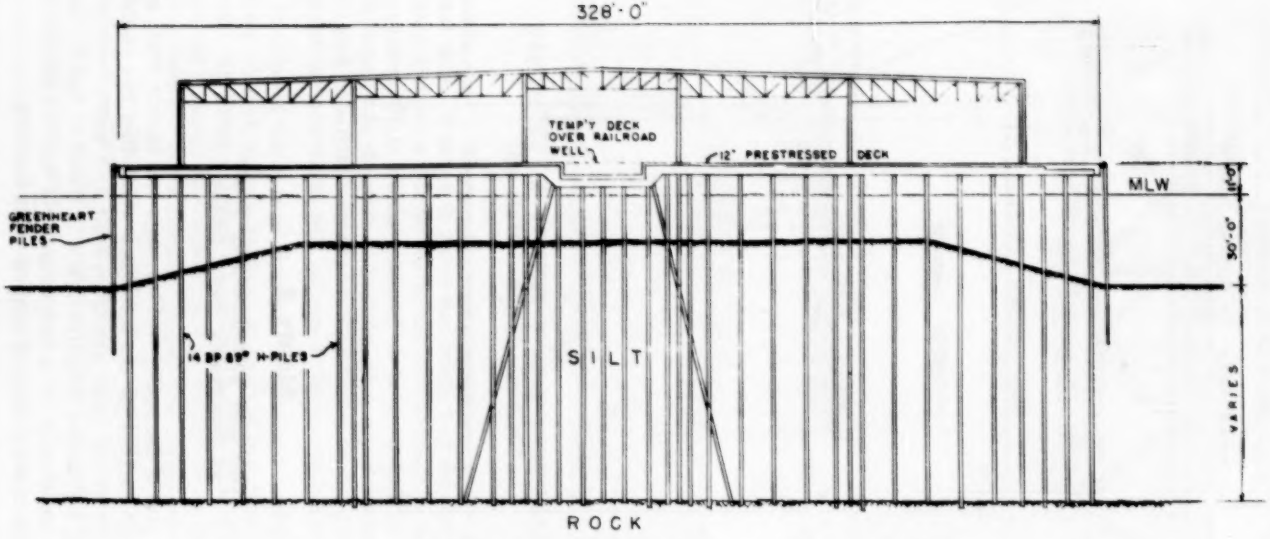



FIGURE 4 - HOBOKEN PIER - TYPICAL SECTION

by masters who are unfamiliar with the port. A further point to be considered, however, is that if the ship is sailing on a tight time schedule, there will be less time available for cautious handling and berthing.

The estimation of approach speeds at berthing is thus a matter of judgment for the designing engineer in consultation with ship owners, pilots, and others with knowledge of local conditions. It should be noted that the "approach speed" referred to in this discussion is the speed in a direction normal to the face of the pier. In the case of an oblique approach, which is of course the general rule, the resolved component in a normal direction must be used for design computations.

It is the author's experience that ship owners and pilots often underestimate the maximum probable approach speed and quote very low figures. One of the Navy design manuals until quite recently specified a design figure of 1/6-knot (equal to 0.3 feet per second), which is certainly too low. At the other extreme, some bridge engineers assume approach speeds of 3 or 4 feet per second when designing bridge piers against accidental lateral loading,—figures which are too high for general use in port and harbor design.

In practice a figure of 1 foot per second is commonly used for piers in enclosed harbors, but in other cases figures as low as 1/2 foot per second, or, in exposed situations, as high as 1-1/2 or 2 feet per second are sometimes adopted.

The computation of impact forces

If the assumption is made that 40 per cent of the ship's kinetic energy is the amount of energy that is absorbed by the deformation of the structure, then

$$\frac{P\delta}{2} = \frac{0.4\ mv^2}{2g}$$

from which P can be computed for various values of $\delta$.

(where m = the weight of the ship
v = the speed of approach
P = the maximum force of the ship on the structure
$\delta$ = the maximum deflection of the structure at the point of impact).

The two principal assumptions are that (a) the pier structure acts as an elastic spring; and (b) the 40 per cent of the ship's energy that is assumed to be absorbed by the deformation of the structure is the residue after allowing for impact and other losses such as the loss due to the elastic deformation of the ship's hull and the oblique angle of approach. The figure of 40 per cent is essentially empirical. Some research on the subject was undertaken by H. T. Horsfield in 1948,[1] but no conclusive results were reached.

A further energy equation is required when the mass of the pier is large compared with the mass of the ship:-

$$Mv = (M + m)V$$

and the effective kinetic energy to be absorbed is

1. "The impact of a vessel with a pier" by H. T. Horsfield,—The Dock and Harbour Authority - June 1948)

$$\frac{0.4(M + m)V^2}{2g}$$

(where $v$ = the speed of the ship before impact
$V$ = the speed of the ship and pier structure immediately after impact
$M$ = the weight of the ship
$m$ = the weight of the pier structure.)

The above momentum equations are not required for piers or structures which do not have a heavy deck structure. If the structure has a heavy concrete deck, the use of these equations gives a slightly lower figure for the kinetic energy.

Working stresses

In considering the allowable working stress, it should be borne in mind that the estimated speed of approach which has been discussed is the assumed maximum probable speed of a ship which is not under proper control. This condition is in some respects analogous to designing for earthquake shocks or hurricanes, in the sense that severe impact loading is a contingency which will not be a regular occurrence, and higher working stresses are therefore permissible.

The advantage of adopting a high working stress lies in the greatly enhanced energy absorption which ensues, since the elastic energy of deformation in bending is proportional to the square of the working stress. If, for example the working stress is doubled, the energy absorption is multiplied by four. In this paper, stress 50 per cent greater than normal working stresses are used as allowable stresses.

In timber structures, the flexural stress at failure may be as high as 6,000 psi, and this is the reason for the well-known reserve of strength which timber piers and dolphins show when subjected to impact loads. (The subject of stresses in timber and steel dolphins has been fully discussed in a paper by D. H. Little to the Britich Institution of Civil Engineers in 1949.)[2]

The adoption of high working stresses is of course contingent upon the assumption of a maximum probable value for the berthing speed. If the assumed berthing speed is a normal speed occuring frequently, then ordinary working stresses should be used.

Fenders

The design of fendering, which has in the past been considered as of minor importance compared with the design of the pier structure itself, has lately attracted increasing attention from Engineers. Spring fenders of the coil-spring and rubber buffer types have been fitted to a number of piers and jetties which have been constructed in recent years.[3] The suspended gravity fender, developed during the last world war, has also been installed in a number of ports.[4]

In this paper it is not proposed to discuss fender design in any detail. The subject has been treated comprehensively by Mr. Little in a recent paper to

2. "Some Dolphin Designs" by D. H. Little, Journal I. C. E. November, 1946.
3. "Oil-loading docks in Venezuela built of welded steel" by Theodore T. Knappen. Civil Engineering, March 1949.
4. "Huge oil pier built in open water" by D. C. Wolfe. Engineering-News Record, May 25th, 1952.

the Institution of Civil Engineers,[5] and also in an article by Mr. Robertson.*

It should be noted, however, that special attention to fendering design is essential if the structure itself is rigid, and in the past the need has been met with brushwood fenders, camels, or catamarans floating alongside the face of the pier, which absorb the energy of impact by crushing of the timber. Spring fenders or gravity fenders are refinements of these traditional expedients, and on rigid structures their value in minimizing impact loads on the structure or damage to the ship's hull is indisputable.

For a structure as flexible as the type of pier illustrated in figure 3, a rubbing face only is required, and the fenders are not called on to absorb energy. Although in practice the fenders will be crushed to a limited extent, the amount of energy absorbed will be small compared with the energy absorbed by the structure itself, and may be neglected.

It is to be expected, therefore, that the fenders on this type of pier will be subjected to less wear and tear, and will have a longer life; and a general conclusion may be drawn that a flexible structure will show an economy in the cost of fender maintenance in addition to the economy of low initial construction cost due to the reduction of the lateral loading.

## The Guayacan Bay Pier

### Design Principles

Guayacan Bay is the loading point for iron ore from the ore-handling plant of the Bethlehem Chile Iron Mines. The type of pier construction adopted,—a deck structure carried on two rows of H-piles, without batter piles or underwater bracing (see figure 3),—is designed to facilitate easy erection from the land, without the use of floating equipment. All the trusses are prefabricated and are used as templates to guide the piles during driving. On completion of the steelwork erection the reinforced concrete deck slab is poured, the forms being carried on the structural steel members.

The pier deck is designed to carry H-20 truck loading and also a travelling ore loader. When lateral impact loads are considered,—an important consideration for this type of pier, which has no batter piles,—the deck slab and steel trusses are assumed to act as a composite beam, continuous for the 700-foot length of the pier, and supported by the H-piles acting as embedded cantilevers when resisting horizontal loads. The whole length of deck is therefore in effect a beam on elastic supports, and the design analysis, which takes into account the relative deflection of the pier deck and the H-piles, shows how the load is distributed.

### Berthing impact loads

In view of the sheltered situation of the pier, and since berthing is effected by first making fast a line to a mooring buoy and then warping the ship alongside, the assumed approach speed of 1 foot per second is not likely to be exceeded. The effective kinetic energy of a ship with a deadweight tonnage of 14,000 long tons will be

$$\frac{0.4\ mv^2}{2g} = \frac{0.4 \times 14{,}000 \times 2240}{2 \times 32 \times 1000}$$

$$= \underline{197 \text{ foot kips}}$$

5. "Some designs for flexible fenders" by D. H. Little. Proc. Inst. C. E., February, 1953.

* "Fendering, Lead-in Jetties and Dolphins" by A. M. Robertson - The Dock and Harbour Authority - May 1953 .

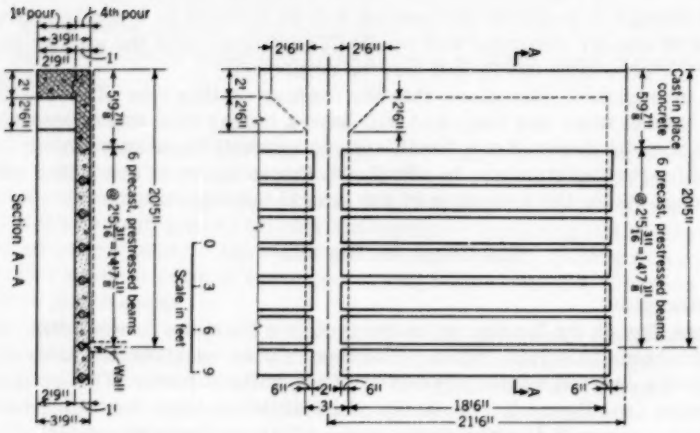



**Figure 5. Plan and section show arrangement of pretensioned stringers, which rest on cast-in-place pile caps. Pile caps will be post-tensioned. (From Civil Engineering, Feb. 1954)**

H-piles in bending

Figures 6 & 7 illustrate the mode of deflection assumed for an individual pile bent and also for the deck of the pier when lateral loads are applied.

Appendix 'A' and figure 8 summarise the results of the design computations for a lateral impact load applied to the pier deck at the center, quarterpoint, and the end of the pier. The design criterion for the maximum permissible lateral load is that the combined bending and direct stressed in the piles shall not exceed the stresses permitted by the A. I. S. C. column formula. It is found in this case that the maximum lateral load (allowing 50 per cent overstress) produces a deflection of the deck of 5.8".

In computing the pile bending stresses, no attempt was made to evaluate the passive earth pressures on the embedded portion of the pile, since the necessary soil data was not available. A point of virtual fixity was assumed 8 feet below the sea bed, and since the soil was a dense gravel, the assumption is considered to be a conservative one. In any event, a small variation in the assumed depth of the point of fixity would not have any significant effect on the result.

When the first analysis of deflections and loads shown in figure 8 (case A) had been completed, and the comparative weakness of the ends of the pier was appreciated, it was decided that some stiffening of the ends was necessary.

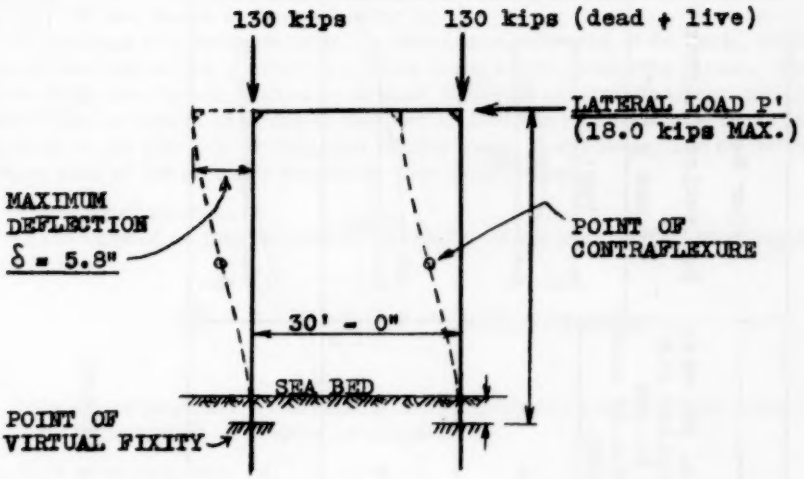



Figure 6. Lateral Force and Deflection diagram for one pile bent.

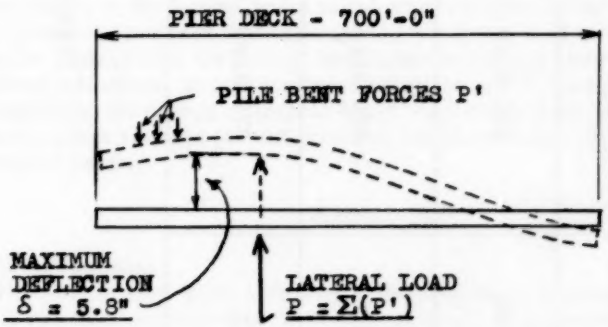



Figure 7. Lateral Forces and Deflection diagram for pier deck.

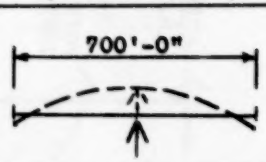
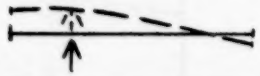
| Point of application | Maximum lateral load 'P' | | Pier Deck Deflection Diagram ($\delta$ max = 5.8") |
|---|---|---|---|
| | CASE A. 14 BP 117# H-piles at 7'-0" on centers throughout. | CASE B. As for case A, but with 14 WF 158# H-piles for the 14 bents in the 100-ft. section at each end of the pier. | |
| CENTER | 980 kips | 995 kips |   |
| ¼-POINT | 880 kips | 975 kips |  |
| END | 270 kips | 390 kips | |

Figure 8. Maximum permissible lateral loads on pier

The 14 BP 117# piles originally proposed for the full length of the pier were replaced by 14 WF 158# piles for the 14 bents at each end, resulting in a 50 per cent increase in the stiffness of the ends. The revised values of the lateral load 'P' are shown in figure 8 (case B).

In arriving at a decision as to the necessary stiffening of the ends, application of the load at the quarter-point was taken as the governing factor. The ends of the pier are protected by 40-foot diameter sheetpile caisson dolphins, which are located at each end of the pier so that their fendering is three feet in front of the pier fender line, and impact loads of any magnitude on the extreme ends of the pier are therefore very improbable.

Pier energy absorption

In the case of an impact load on the center of the pier, the energy absorption is thus

$$\frac{P\delta}{2} = \frac{995 \times 5.8}{2 \times 12} = \underline{240 \text{ foot kips}}$$

This figure provides a reasonable margin over the design requirement of 197 foot kips, and was accepted as satisfactory.

Further investigations

The importance of energy methods of analysis of a structure under impact loads lies in the general picture of its behaviour that can be presented rather than in attempting to compute design stresses with great accuracy, and in this respect graphs similar to figures 9, 10, and 11 are of great assistance.

Figure 9 shows the increase in effective kinetic energy with the square of the speed. Large ships moving at any appreciable speed have enormous kinetic energies and produce correspondingly heavy loads on the structures unless the energy is adequately absorbed.

Figure 10 shows the maximum lateral load on the pier and the substantial decrease in load that can be obtained by providing an adequate deflection.

Figure 11 shows the structure's resistance to impact loads for varying lengths of pile, the effective length of the pile being the distance from the lower chord of the lateral truss to the point of virtual fixity in the sea bed. It is interesting to note that although the allowable load is less for a long pile than for a short one, the energy absorption is greater, because of the increased deflection. A long unbraced length of pile is therefore advantageous in absorbing the energy of impact loads, and, conversely, any system of rigid bracing which reduces the deflection of the pile would reduce the resistance to impact loads.

## Hoboken Pier

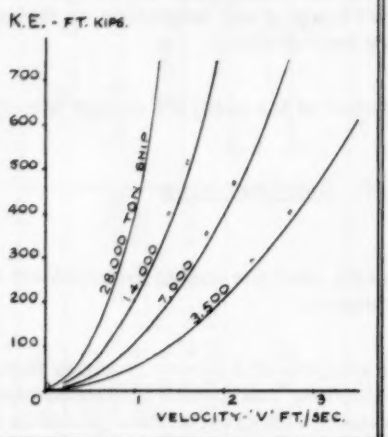
Design Principles

The Port of New York Authority's Hoboken Pier, (a general description of which has been published in Civil Engineering[6]) is a general cargo terminal pier designed to accommodate C.2, Liberty, or Mariner class merchant ships. The pier, with an overall length of 700 feet and a width of 328 feet, is of prestressed concrete construction supported on steel H-piles. It is not structurally connected to the shore, since there is a 1-1/2-inch expansion gap at the

6. "Prestressed deck proves cheapest for new Hoboken pier," by Theodore O. Blaschke and David A. Hopkins. Civ. Eng., February, 1954.

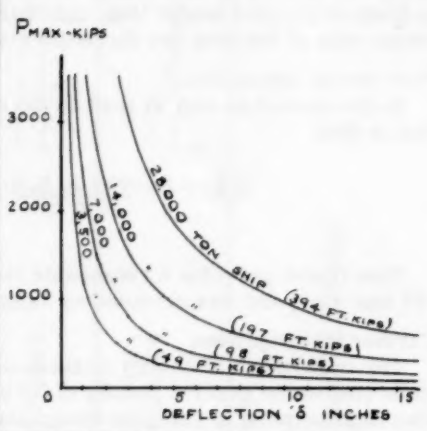
## GUAYACAN BAY PIER

### GENERAL RELATIONSHIP - LOAD, DEFLECTION, & K.E.




GRAPH OF EFFECTIVE KINETIC ENERGY ($= 0.4\frac{mv^2}{2g}$) FOR SHIPS OF VARIOUS TONNAGES MOVING AT A VELOCITY 'V' FT./SEC.

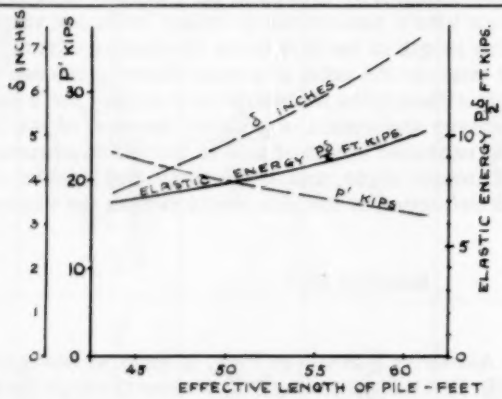
Figure 9




GRAPH OF MAXIMUM LATERAL LOAD PLOTTED AGAINST DEFLECTION FOR VARIOUS VALUES OF ELASTIC ENERGY EQUAL TO A SHIP'S KINETIC ENERGY WHEN MOVING AT 1 FT./SEC.

Figure 10

### LOAD & DEFLECTION & ELASTIC ENERGY FOR 2-PILE BENT




GRAPH OF ELASTIC ENERGY OF 2-PILE BENT OF GUAYACAN BAY PIER FOR A VARYING EFFECTIVE LENGTH OF PILE.

(PILE STRESSED TO 18,000 PSI PLUS 50 PER CENT IN EACH CASE.)

Figure 11

inshore end. The gap is provided with keys, which restrain this end of the pier from lateral movement, but do not provide fixity. The offshore end of the pier is free to deflect under lateral loads.

Figure 4 shows a typical cross section, and figure 5 is a detail of the deck stringers. The sequence of construction was as follows:-

1) The pile caps,—21'-6' on centers,—were poured with ducts embedded for post-tensioning cables running the length of each pile cap.

2) The precast prestressed concrete stringers were laid in place, spanning between pile caps.

3) The concrete in the upper section of the pile cap beam and in the keys between the stringers was poured, so that the poured concrete was flush with the upper surface of the stringers.

4) The pile cap beams were post-tensioned.

The purpose of the post-tensioning is to provide a lateral compression in the pier deck, and thus insure that the concrete deck will be monolithic. The compressive stress induced in the deck in this manner is low,—less than 100 psi,—but it is sufficient to eliminate the risk of shear failure between stringers in a longitudinal direction. Without the post-tensioning there would be no positive provision against distortion of the deck and failure in shear when subjected to lateral loads from berthing ships.

Impact loads

The design provisions for lateral loading on the pier are either the impact energy of a ship of 25,000 short tons deadweight moving at 1 foot per second, or a concentrated load of 1,500 kips.

If the weight of the offshore half of the concrete pier is assumed to be 30,000 kips, then, using the momentum and energy equations

$$50{,}000 \times 1 = (50{,}000 + 30{,}000) \times V$$

$$\text{and } V = 5/8 \text{ foot per second.}$$

And the effective kinetic energy

$$= \frac{0.4 \times 80{,}000 \times (5/8)^2}{2 \times 32}$$

$$= \underline{195 \text{ foot kips}}$$

H-pile loading

Since the 14BP89# H-piles were from 90 to 150 feet long, driven to a point bearing on rock through soft silt, a design investigation was undertaken based on the analyses of Cummings[7] and Glick[8] in order to determine the permissible loads—both in bearing and in a lateral direction—which the piles would carry. The results were of course dependent on the value assigned to the lateral soil modulus, for which there is no generally acceptable method of

7. "The stability of Foundation Piles against Buckling under Axial Load," Proc. Highway Research Board December 1938, by A. E. Cummings.
8. "Influence of Soft Ground on the Design of Long Piles," by G. W. Glick. Proc. 2nd Inter. Conf. Soil Mechanics 1948 Vol. IV.

computation or standard soils laboratory procedure. There was also some doubt as to what extent the theoretical considerations upon which the analyses were based would be realised in practice.

The conclusions reached were as follows:-

a) The safe bearing load would be 90 tons per pile. It was stipulated, however, by the design engineers that this figure should be confirmed by the proof loading of a test pile to 150 tons before construction was commenced.

b) When subjected to lateral loads, the piles would act as embedded cantilevers, with a length of approximately 60 feet from the lower point of virtual fixity in the silt to the upper point of fixity in the pile cap beam.

c) It would be unwise to rely solely on the cantilever strength of the H-piles for the pier's resistance to lateral loads in view of the uncertainties involved in the design analyses. Batter piles were therefore required to provide lateral resistance, and

d) The maximum lateral deflection of the pier would be governed by the permissible deflection of the batter pile bents,—computed to be 0.24 feet.

Other assumptions relating to the design for lateral loading were that:

e) As a worst case the impact load would be applied to one of the knuckles at the offshore end of the pier.

f) The deflection of the pier would be a maximum at the offshore end and zero at the inshore end, which is laterally restrained.

g) Only 550 of the bearing piles and 40 of the batter piles, which are located in the offshore half of the pier, would be effective in resisting lateral impact.

Energy absorption

Appendix 'B' summarises the design computations for the absorption of energy arising from lateral impacts. The total energy absorption—462 foot kips—is more than double the design requirement of 195 foot kips. The pier thus possesses a big reserve of resistance to lateral loads. Further, it may be noted that the fendering—consisting of greenheart fender piles backed by southern pine wales—provides an additional reserve of energy absorption, consideration of which has not been included in this paper. The margin available for collision risks is therefore even greater than indicated by the above figures. This margin is considered a wise form of insurance in a structure designed to have a life of 100 years.

## CONCLUSIONS

The figures quoted in this paper are not intended to give exact figures of loads and deflections, since the velocity of a berthing ship can never be estimated with precision or certainty. However, the formulation of energy equations will often give the port and harbor engineer a sense of perspective when dealing with lateral loads.

It is hoped that this paper will lead to discussion and the wider application of energy absorption criteria. It appears that investigation into cases of pier damaged by berthing ships will provide guidance for design engineers in the future.

## APPENDIX 'A'

Design assumptions for a 2-pile bent. (see figure 6.)

1. Horizontal cross-member assumed completely rigid.
2. Piles assumed to have a theoretical point of fixity 8 feet below sea bed.
3. Piles considered as columns with combined bending and direct stresses. $\frac{f_a}{F_A} + \frac{f_b}{F_B}$ must not exceed 1.
4. Allowable compressive stress $F_A$ is taken as column load + 50% for a 52 foot column = 17,600 psi. (short column length allows for soil support at foot of pile.)
5. Allowable bending stress $F_B$ is taken as 18,000 + 50% = 27,000 psi.

Then maximum load (direct compression) on pile
$= 130 + \frac{55}{30} P'$ kips.

Maximum bending moment in pile
$= \frac{55}{4} P' + 130 \frac{\delta}{2}$

Obtaining corresponding equations for direct and bending stresses, and solving graphically $\frac{f_a}{F_A} + \frac{f_b}{F_B} = 1$,

$P'_{max.} = 18{\cdot}0$ kips, & $\delta_{max.} = 5{\cdot}8"$.

Design assumptions for pier deck (see figure 7.)

1. Resisting force of pile bents $P'$ varies with deflection '$\delta$', and has a maximum value of 18·0 kips when $\delta = 5{\cdot}8"$.
2. Deflection equation is $EI \frac{d^4y}{dx^4} = -ky$
3. $I$ = moment of inertia of deck considered as cracked section of reinforced concrete beam + 50% of the longitudinal steel in the trusses = $120 \times 10^6$ inches.$^4$
4. Resistance modulus $k = 37$ lbs/inch deflection/inch length.

General solution for beam of infinite length is
$y = \frac{P\beta}{2k} \cdot e^{-\beta x} (\cos \beta x + \sin \beta x)$, where $\beta = \sqrt[4]{\frac{k}{4EI}} = .00042$.

And for beam length '$\ell$' with center load,
$y_{max.} = \frac{P\beta}{2k} \left( \frac{\cosh \beta\ell + \cos \beta\ell + 2}{\sinh \beta\ell + \sin \beta\ell} \right)$

Values of P given in figure 8 are all computed for $\delta_{max.} (= y_{max.}) = 5{\cdot}8"$.

## APPENDIX 'B'—HOBOKEN PIER

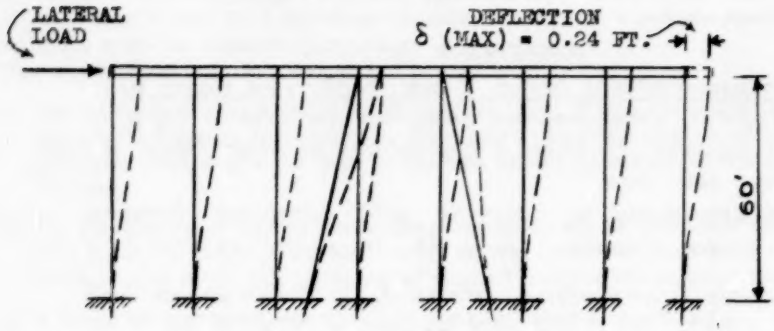



DIAGRAM - LATERAL DEFLECTION

All piles 14 BP 89#, I = 909.1 in $^4$
Maximum pile loading = 90 + 50 per cent = 135 tons
Maximum pile length = 150 feet

Maximum permissible lateral load for batter pile bents (2 batter piles in each bent) = 55.5 tons
Note: Batter pile loading computed by simple statics
Uplift governs on left hand batter pile.
Maximum permissible lateral load on 20 batter pile bents
= 20 x 55.5 = 1,110 tons

ENERGY ABSORPTION - BATTER PILES

If maximum axial compression or extension of batter piles is computed on full 150-foot length,
Maximum permissible deflection of pile bent = 0.24 feet

$$\text{Therefore energy absorption} = \frac{0.24 \times 1{,}110 \times 2}{2}$$

$$= 264 \text{ foot kips}$$

ENERGY ABSORPTION - BEARING PILES

If maximum permissible lateral deflection of pier = 0.24 ft. and the bearing piles are considered to act as embedded cantilevers fixed top and bottom 60 feet long,

Maximum permissible lateral load = 3 kips per pile
On 550 piles maximum permissible lateral load = 550 x 3
= 1650 kips

$$\text{Therefore energy absorption} = \frac{1650 \times 0.24}{2} = 198 \text{ foot kips}$$

TOTAL ENERGY ABSORPTION = 264 + 198 = 462 FOOT KIPS

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## VOLUME 80 (1954)

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## VOLUME 81 (1955)

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MARCH: 634(PO), 635(PO), 636(PO), 637(PO), 638(PO), 639(PO), 640(PO), 641(PO)[c], 642(SA), 643(SA), 644(SA), 645(SA), 646(SA), 647(SA)[c], 648(ST), 649(ST), 650(ST), 651(ST), 652(ST), 653(ST), 654(ST)[c], 655(SA), 656(SM)[c], 657(SM)[c], 658(SM)[c].

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c. Discussion of several papers, grouped by Divisions.

e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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